Saskatchewan
Ministry of
Agriculture

IRRIGATION

Irrigation Scheduling Manual

What is irrigation scheduling?

Irrigation scheduling, or irrigation water management, ensures that water is consistently available to the plant and that it is applied according to crop requirements.

Proper irrigation scheduling will improve profitability and water use efficiency by:

1. maximizing crop yield and quality;
2. decreasing water lost through deep percolation and runoff; and
3. optimizing pumping costs.

To effectively schedule irrigation applications, four key pieces of information need to be known:

1. soil texture;
2. water holding capacity of the soil;
3. soil moisture content; and
4. crop water use at the specific development stage.

Another factor that should be considered within a scheduling program is knowing the allowable depletion of the crop, that is how much water can be removed from the soil profile prior to stressing the crop.

The limitations of an irrigation system can impact a scheduling program, so it is necessary to be aware of how much water can be applied efficiently to the crop and the time duration required to apply a specific amount of irrigation.

This publication is intended to provide irrigators with the information they need to properly schedule irrigation on their farms.

Soil texture

The first step an irrigator must take when scheduling irrigation is to determine the soil texture of the field to be scheduled.

Soil texture is concerned with the size of mineral particles. It refers to the relative proportions of sand, silt and clay in a given soil. These relative proportions of sand, silt, and clay are described by classes of soil texture shown in Figure 1.

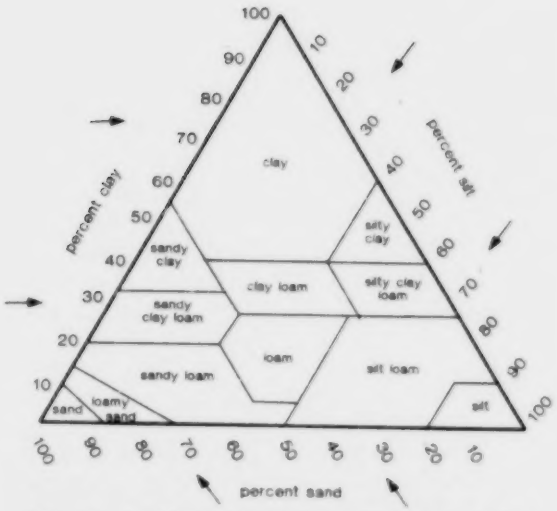


Figure 1. A soil textural triangle illustrating the percentages of sand, silt, and clay in the soil classes.

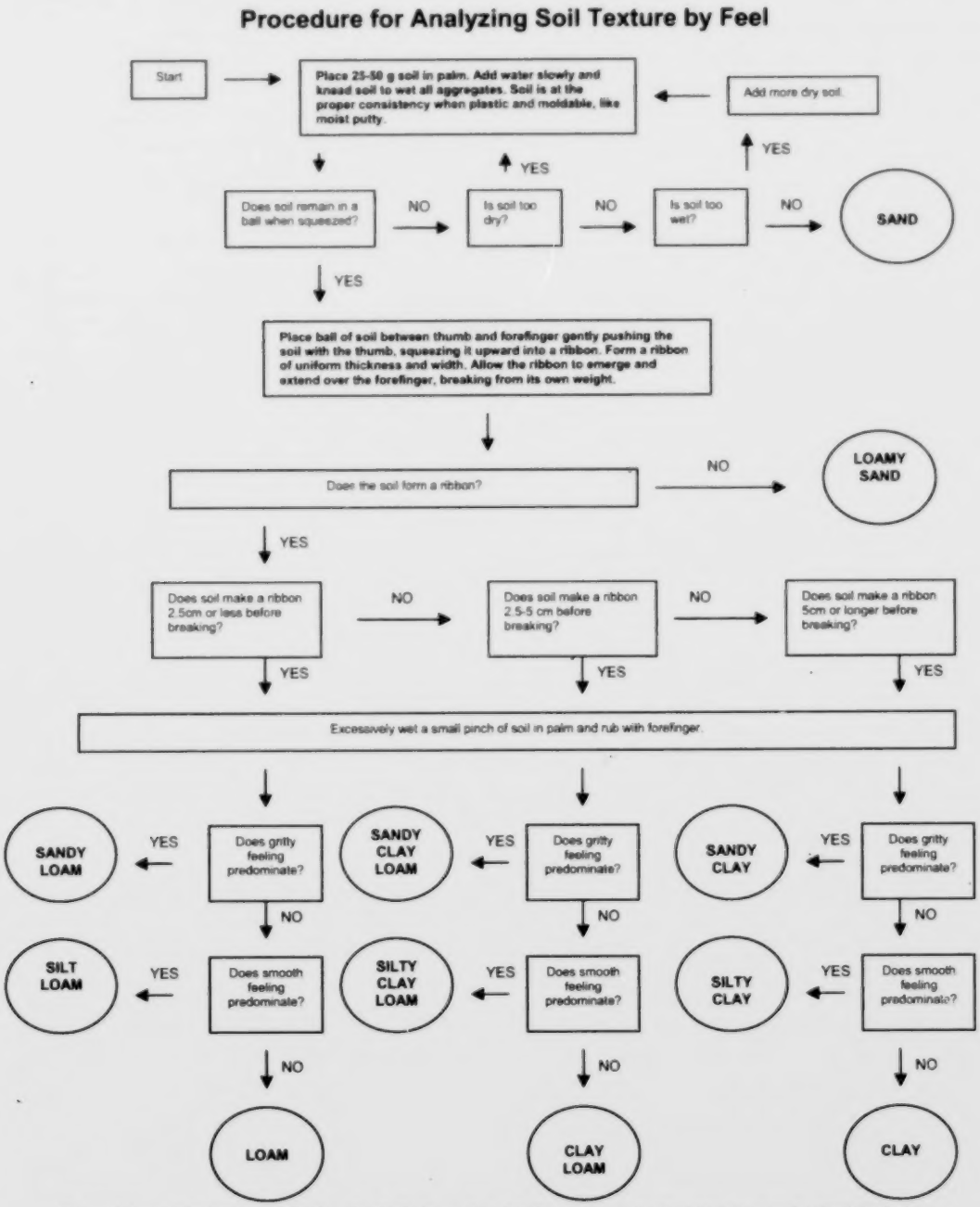
To effectively manage irrigation operations through appropriate scheduling techniques, soil texture must be determined.

Texture can be estimated by wetting soil and kneading it between the thumb and forefinger (Figure 3 below).

Sand feels gritty, silt feels slippery and clay feels sticky. The term loam is used when the soil consists of significant portions of all three textures. The amount of soil water held in the soil will vary from texture to texture. Sandy soils hold less water than clay soils.

Figure 3: Forming a soil ribbon.

Figure 2 below illustrates the procedure to determine soil texture using the feel method. Soil texture can also be determined by referring to the field's Agro-Environmental Report or a Saskatchewan soils map.


Procedure for Analyzing Soil Texture by Feel
Start
Place 25-50 g soil in palm. Add water slowly and knead soil to wet all aggregates. Soil is at the proper consistency when plastic and moldable, like moist putty.
Add more dry soil.
YES
YES
Does soil remain in a ball when squeezed?
NO
Is soil too dry?
NO
Is soil too wet?
NO
SAND
YES
Place ball of soil between thumb and forefinger gently pushing the soil with the thumb, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over the forefinger, breaking from its own weight.
Does the soil form a ribbon?
NO
LOAMY SAND
YES
Does soil make a ribbon 2.5cm or less before breaking?
NO
Does soil make a ribbon 2.5-5 cm before breaking?
NO
Does soil make a ribbon 5cm or longer before breaking?
YES
YES
YES
Excessively wet a small pinch of soil in palm and rub with forefinger.
SANDY LOAM
YES
Does gritty feeling predominate?
SANDY CLAY LOAM
YES
Does gritty feeling predominate?
SANDY CLAY
YES
Does gritty feeling predominate?
NO
NO
NO
SILT LOAM
YES
Does smooth feeling predominate?
SILTY CLAY LOAM
YES
Does smooth feeling predominate?
SILTY CLAY
YES
Does smooth feeling predominate?
NO
NO
NO
LOAM
CLAY LOAM
CLAY

Determining soil texture by the "feel method". Redrawn from "*A Flow Diagram for Teaching Texture-by-Feel Analysis*", by Steve J. Thien, Journal of Agronomic Education, Vol.8, 1979, pp.54-55.

Figure 2. Hand feel texturing method.

Water holding capacities

The second step an irrigator must take when scheduling irrigation is to determine the water holding capacity of the soil. This information can be obtained from charts which provide information based on soil texture.

Soil is composed of a solid phase, a liquid phase, and a gaseous phase. The solid phase consists of mineral particles and organic materials and can comprise between 30 and 60 per cent of the total soil volume. The remainder of soil volume consists of air and water which are located in pore space between the solid soil particles. Total porosity refers to the volume of soil that is not occupied by the solid soil components. The size, shape, and distribution of soil pores are all largely affected by the texture of the soil. These properties all affect the movement and retention of water in soils.

Water is retained in soils because of attractive forces such as adhesion and cohesion. Adhesion refers to the attraction of the solid soil particles to water and cohesion refers to the attraction of water to itself. The matric potential of a soil refers to how strongly the water is held by the soil or, more specifically, how much energy it would take to remove the water from the soil. The energy required to remove water from the soil increases as the size of individual soil pores decreases. This is why heavier textured clay soil tends to have more, but smaller pores, and is able to retain more water than lighter, sandy soils which have larger sized pores from which water is more freely drained.

A soil is considered to be saturated when the entire pore volume is filled with water. When the soil pores are full to capacity, water cannot be retained by the soil as the water will drain quickly through the large pores. The term field capacity refers to the amount of water that can be held by the soil after the effects of gravity cease. This period will vary depending on the texture of the soil with lighter textured soils draining faster than heavier textured soils.

Wilting point or permanent wilting point is the soil water content at which the plant can no longer extract water from the soil. Although there is still water in the soil at this point, the water is held too strongly by the soil for the plant to utilize.

Available water, also referred to as available moisture, is the amount of water the soil holds between field capacity and wilting point. It is the water that is considered to be available for crop consumption.

Table 1 on the next page lists the average available water of various textural classes of soils in Saskatchewan.

However, not all available water is able to be utilized equally by the plant. As the amount of water in the soil gets closer to wilting point, it becomes increasingly difficult for a plant to extract the available water.

Figure 4 below illustrates the definition of available water in reference to varying soil textures.

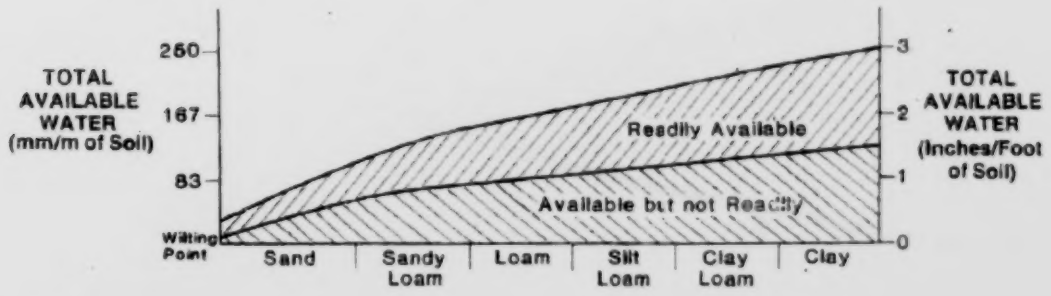


Figure 4. Estimated available moisture for various soil textures.

Table 1. Average physical soil characteristics.

Texture	% Field Capacity *	% Wilting Point *	% Available Moisture Holding Capacity *	Available Moisture	Infiltration Rate **	
				inches/foot	mm/hr	in/hr
Loamy Sand (LS)	10	5	5	0.84	25	1.00
Sandy Loam (SL)	18	8	10	1.68	18	0.70
Fine Sandy Loam (FSL)	20	9	11	1.85	15	0.60
Very Fine Sandy Loam (VL)	22	10	12	2.02	13	0.50
Silt Loam (SiL)	22	10	12	2.02	9	0.35
Loam (L)	24	12	12	2.01	8	0.30
Clay Loam (CL)	26	13	13	2.23	6	0.25
Clay (C)	40	22	18	3.02	4	0.15

* From studies done randomly throughout the Dark Brown Soil Zone
** Field experience and testing done by O.P. Bristol. Per cent expressed by weight.

Methods of monitoring soil moisture

There are a number of methods in use by irrigators to schedule water. The four most commonly used methods are:

- the feel method;
- the moisture monitoring equipment method;
- the crop canopy temperature equipment method; and
- the computer model and weather data information method.

First method: The feel method of monitoring soil moisture

The feel method incorporates the use of a soil probe and the ability of the irrigator to estimate how wet or dry a soil is.

Soil textures behave with specific characteristics relative to the amount of water they contain.

With experience, an irrigator can provide an accurate description of a soil's moisture content.

Table 2 provides a descriptive guide for determining the available moisture of varying soil textures.
Figures 5, 6 and 7 are examples of soil probes that are currently available for use in a scheduling program.

Probe the soil at one foot increments, and firmly squeeze a handful to determine the moisture content.

It is important to probe more than one site within the field.

By utilizing the feel method, an irrigator can estimate how long the soil moisture reserve will supply a crop without affecting its yield.

This is especially crucial during the critical development stages of crops and when determining to shut down the irrigation system prior to harvest.

Table 2. Soil moisture evaluation by the "Feel" Method

Per cent of Available Moisture	Sandy Loam	Loam	Clay Loam
0 - 25	Dry, loose, flows through fingers	Powdery, sometimes slightly crusted but easily broken down into powdery conditions	Hard, baked, cracked; difficult to break down into powdery condition
25 - 50	Appears to be dry, will not form a ball with pressure	Somewhat crumbly but will hold together from pressure	Somewhat pliable, will ball under pressure
50 - 75	Tends to ball under pressure but seldom will hold together when bounced in the hand	Forms a ball, somewhat plastic, will slick slightly with pressure	Forms a ball, will ribbon out between thumb and forefinger, has a slick feeling
75 - 100	Forms a weak ball, breaks easily when bounced in the hand, will not slick	Forms a ball, very pliable, slick readily	Easily ribbons out between thumb and forefinger, has a slick feeling
100 (Field capacity)	Upon squeezing no free water appears on soil, but wet outline of ball is left on hand, soil will stick to thumb when rolled between thumb and forefinger	Same as sandy loam	Same as sandy loam

The photographs on this page illustrate the appearance of soil when it contains varying percentages of moisture. This source of this material is the document entitled *Estimating Soil Moisture by Feel and Appearance* published by the United States Department of Agriculture (USDA) Natural Resources Conservation Service, 1998.

Sandy loam and fine sandy loam soils

25-50% available moisture

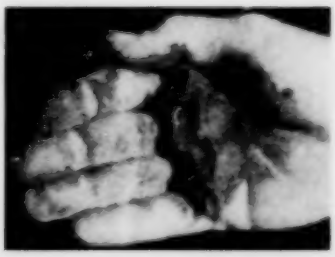
50-75% available moisture

75-100% available moisture

Sandy clay loam, loam and silt loam soils

25-50% available moisture

50-75% available moisture

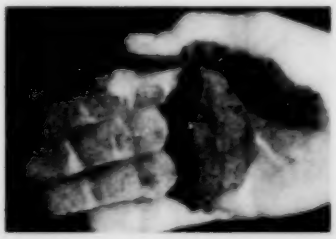


75-100% available moisture

Clay, clay loam, loam and silt loam soils

25-50% available moisture

50-75% available moisture

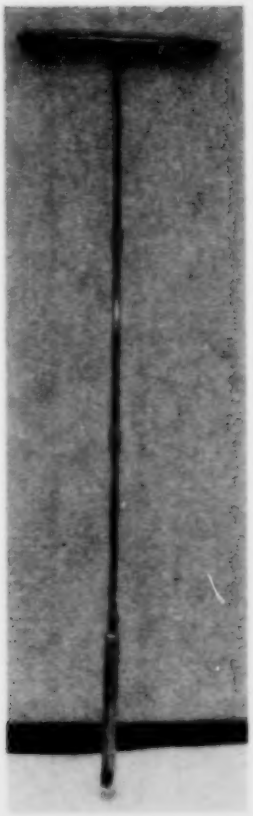


75-100% available moisture

Tools for taking soil samples

Oakfield Model B

- Suitable for any type of irrigation.
- Can be pushed down to a three-inch depth.
- Requires more physical exertion to push into or pull out of the ground.
- Available with sampling tube and auger.
- Estimated cost $125.



Left: Figure 5.
Oakfield Model B

The Clements Backsaver

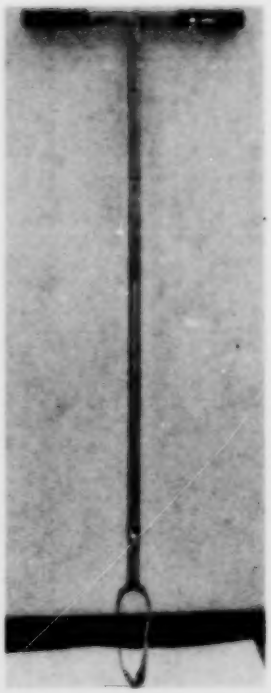
- Deluxe model of the soil sampler.
- Equipped with foot pedal to make insertion easier and a cleaning tool to avoid skinned fingers.
- Estimated cost $500.

Above. Figure 6.
Clements Backsaver

The Dutch Auger

- Optimal for heavy, solonetzic and/or stony soils.
- Can be purchased in different shapes for special applications or with an extension handle for deeper sampling.
- Estimated cost $150.

The T-bar with a ball bearing has limitations for use with irrigation scheduling, but is a soil probe that can be assembled on-farm and utilized to determine the depth of the wetting front.



Left: Figure 7.
Dutch Auger

Second method: Monitoring equipment and installation method — tensiometers and electrical resistance blocks

Moisture monitoring equipment can be used in conjunction with the feel method to assist an irrigator in determining soil moisture content. Two types of soil moisture monitoring equipment are tensiometers and electrical resistance blocks.

Tensiometers

A tensiometer monitors soil moisture changes using the principle of soil suction or tension. The ceramic tip allows moisture to pass from the tensiometer into the soil as the soil dries out. As the moisture leaves the sealed tensiometer, the vacuum gauge reading rises. If the soil approaches the crop's wilting point, air will move into the tensiometer and break the vacuum; the gauge will then read zero and the instrument will require servicing. As the soil is wetted through rain or irrigation, moisture is drawn back into the tensiometer and the vacuum gauge reading falls.

This monitoring system:

- is easy to install and read;
- works well on medium and light textured soils; and
- is not affected by salinity and does not require calibration.

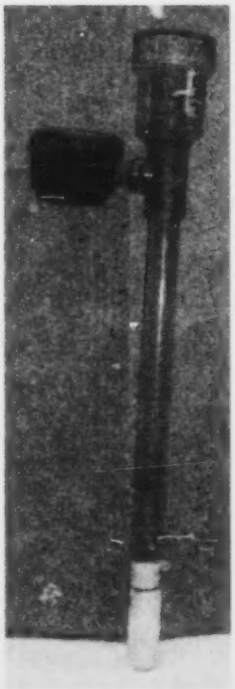
Installation of a tensiometer

The tensiometers should be soaked for 24 hours prior to installation. Protect the ceramic tips from drying while transporting them to the installation site. Make a hole in the soil using a soil probe or steel rod. Using the soil material taken from the depth at which the instrument is being installed, make a soil-water slurry of creamy consistency and place in the hole.

Tensiometers are available in 15-, 30-, 45-, 60-, and 90-centimetre lengths (six-, 12-, 28-, 24-, 36-, and 48-inch lengths).

Make sure there is good contact between the tip and soil to ensure accurate and reliable readings. Backfill around the instrument to ensure that water does not drain and collect in the tensiometer soil space and create artificially increased moisture readings.

Fill the tensiometers with irrometer fluid and use a vacuum pump to raise the gauges to 80 to 85 centibars. Refill with irrometer fluid if necessary and replace the caps.



A 12-inch tensiometer.

Electrical resistance blocks: gypsum blocks and Watermark™ sensors

There are two types of electrical resistance blocks used to monitor soil moisture: gypsum blocks and Watermark™ sensors.

The blocks are made of gypsum cast around two concentric electrodes. Watermark™ sensors share a similar design – a porous ceramic exterior, which contains two electrodes within a matrix structure. The matrix material, similar to fine sand, is surrounded by a protective synthetic membrane and a stainless steel sleeve to protect the sensor from deterioration. Watermark™ sensors also contain a gypsum capsule. The gypsum acts as a buffer against the effects of soil salinity. The concentric electrodes confine the flow of current to the interior of the block or sensor, thus reducing the effects of soil conductivity.

When a block or sensor is buried in the soil it absorbs moisture from the soil or releases moisture into the soil, until its moisture content approaches equilibrium with the moisture content of the soil. It is the moisture changes of the sensor or block that are depicted by differences in electrical resistance. When the block or sensor is connected to a meter, current flows between the electrodes and the electrical resistance is measured. As the soil moisture increases, the resistance between electrodes decreases.

The benefits and drawbacks of Watermark™ sensors are:

- easy to install and read with a meter;
- works well on medium and heavy textured soils;
- does not work well in sandy soils; and
- excess salts in saline and alkaline soils will result in higher than normal readings.

The longevity of Watermark™ sensors is greater than that of gypsum blocks.

Figure 9. Watermark™ sensor and meter

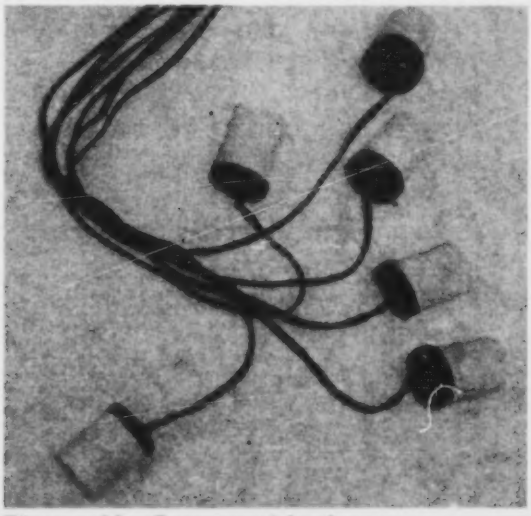


Figure 10. Gypsum blocks

Installation of gypsum blocks

The blocks should be soaked prior to installation and then allowed to dry. Soak the blocks again for two or three minutes before installing them.

Make a hole to the desired depth of the block with a soil probe or steel rod. Using soil material taken from the depth at which the instrument is to be installed, make a soil-water slurry of creamy consistency and place one or two tablespoons of the slurry in the hole.

Ensure the soil texture of the slurry is the same as the surrounding soil to be monitored by the block.

Push the block into the slurry. Leaving the wires protruding to the surface, backfill and tamp the hole in small increments. Be sure the soil replaced is mounded a little above the existing ground level so that water does not collect in the newly formed hole and result in a false reading.

Mark the wires clearly as to location and depth. A common practice is to tie one knot in the shallow one, two knots in the one at the next depth, etc.

Establish a method of recording readings of the blocks as well as other relevant data which will allow you to analyze the data obtained; times and amounts of irrigation, rainfall, crop stage.

Installation of Watermark™ sensors

Watermark™ sensors can be attached to half-inch PVC pipe, cut at various lengths for installation at different depths. Close the top of the pipe with a cap or cork and have the cable running out the top of the pipe.

Prior to installation, sensors should be soaked in water for two hours followed by a 24-hour drying period. Repeat this process twice before installation.

Ensuring the sensor is adequately wet enhances the response mechanism and removes air from the sensors.

Using a soil probe or rod, make access holes for the sensors to the corresponding depths. Typically, sensors are installed at 30, 60 and 90 centimetres (12, 24 and 30 inches), as this provides adequate representation of the root zone. Push the sensor into the hole and backfill around the edge to create a sealed surface.

Site selection

Careful consideration should be given to the location of the monitoring equipment in the field. If the equipment is located on an area of the field which tends to be drier, a knoll for example, the rest of the field may be over-irrigated. Conversely, if the equipment is located in a moister area such as a low spot, then the rest of the field may be under-irrigated. Remember that tensiometers and electrical resistance blocks only measure soil moisture at that location in the field and only at the depth at which they are installed.

Avoid trampling the crop around the site as much as possible. The crop stand should be consistent with growth in the rest of the field.

Choose a convenient, accessible location and mark the location using a Geographic Positioning System (GPS) and/or a visual marker. Avoid field edges, wheel tracks, and end-gun area as the water patterns are adversely affected by wind. A starting point would be to choose a site between the fifth and sixth tower, in an area representative of the field, usually adjacent to the road leading to the pivot point.

Record the rainfall and the water applied by the irrigation system with the use of rain gauges. A rain gauge can be situated outside the irrigated area for rainfall. Two rain gauges may be placed under the irrigation system to calculate the average amount of water applied. Pouring a shallow layer of mineral or vegetable oil into the gauge prevents evaporation until the gauge can be read.

If two soil types are present in the field, each type must be monitored separately. The percentage of the field in each soil type should be considered and factored into water application management.

If two crops are grown under one system, each crop should be monitored and managed separately. Avoid an area next to the junction of the two crops as some distance is required to adjust the rates when applications are not uniform for both crops.

Data interpretation

The rate of movement of readings from soil moisture monitoring equipment will depend on two things:

1. Crop use – The higher the daily crop use, the faster the readings will change.
2. Soil texture – The lighter the soil texture, the faster the readings will change.

Table 3 and Table 4 provide the estimated available moisture for tensiometer and gypsum block readings, respectively. Tables 5 through 8 show the estimated available moisture content readings of Watermark™ sensors for specific soil textures.

Table 3. Estimated per cent available moisture of soil textures in Saskatchewan based on tensiometer readings.

Tensiometer Reading	Clay	Loam	Sandy Loam	Loamy Sand
	Available Moisture (%)			
10	100	100	100	100
20	95	95	75	60
30	95	85	55	45
40	90	75	50	35
50	90	70	45	25
60	85	60	40	25
70	80	50	40	25
80	75	50	35	20

Table 4. Estimated per cent available moisture of soil textures in Saskatchewan based on gypsum block meter readings.

Soil Texture	Sandy Loam	Fine Sandy Loam	Loam	Clay Loam	Clay
Meter Reading*	**Available Moisture (%)**				
10	100	100	100	100	100
9	70	70	100	95	90
8	60	60	90	80	75
7	55	55	85	75	65
6	50	45	80	70	60
5	40	40	70	65	50
4	40	40	60	55	45
3	30	30	50	50	40
2	15	20	35	30	25
1	0	5	10	5	5
0	0	0	0	0	0

Table 5. Estimated per cent available moisture of loamy sand soil texture based on Watermark™ sensor readings. (Neibling, 2003).

Soil Texture Watermark™ Sensor Reading (cbars)	Loamy Sand Available Moisture (%)
10	100
12	85
14	80
15	75
16	70
18	65
20	60
22	55
25	50
35	40
50	30

Shallow Root Zone (<= 0.6m)
(Potatoes, Dry Bean)
0 Saturated soil
10-18 Optimal crop growth
>18 Crop water stress

Deep Root Zone (>= 0.6m)
(Grain, Alfalfa, Corn, Pasture)
0 Saturated soil
10-25 Optimal crop growth
>25 Crop water stress

Table 6. Estimated per cent available moisture of sandy loam soil texture based on Watermark™ sensor readings (Neibling, 2003).

Soil Texture Watermark™ Sensor Reading (cbars)	Sandy Loam Available Moisture (%)
10	100
12	85
14	80
16	75
18	70
20	65
24	60
27	55
30	50
43	40
71	30

Shallow Root Zone (<= 0.6m)
(Potatoes, Dry Bean)
0 Saturated soil
10-24 Optimal crop growth
>24 Crop water stress

Deep Root Zone (>= 0.6m)
(Grain, Alfalfa, Corn, Pasture)
0 Saturated soil
10-30 Optimal crop growth
>30 Crop water stress

Table 7. Estimated available moisture of fine sandy loam or silty loam soil textures based on Watermark™ sensor readings (Neibling, 2003).

Soil Texture Watermark™ Sensor Reading (cbars)	Fine Sandy Loam Silty Loam Available Moisture (%)
10	100
15	85
17	80
20	75
22	70
25	65
30	60
35	55
40	50
62	40
119	30

Shallow Root Zone (<= .6m)
(Potatoes, Dry Bean)
0 Saturated soil
10-25 Optimal crop growth
>25 Crop water stress

Deep Root Zone (>= 0.6m)
(Grain, Alfalfa, Corn, Pasture)
0 Saturated soil
10-40 Optimal crop growth
>40 Crop water stress

Table 8. Estimated available moisture of clay loam soil texture based on Watermark™ sensor readings (Neibling, 2003).

Soil Texture Watermark™ Sensor Reading (cbars)	Clay Loam Available Moisture (%)
30	100
38	85
42	80
45	75
50	70
55	65
62	60
68	55
75	50
100	40
200	30

Shallow Root Zone (<= .6m)
(Potatoes, Dry Bean)
0 Saturated soil
30-62 Optimal crop growth
>62 Crop water stress

Deep Root Zone (>= 0.6m)
(Grain, Alfalfa, Corn, Pasture)
0 Saturated soil
30-75 Optimal crop growth
>75 Crop water stress

Third method: the crop canopy temperature method of measuring soil moisture

Crop canopy temperature can be used as an estimation of available water in the soil. Leaf temperature has been related to crop water stress based on the fact that under stress-free conditions the water transpired by the plant evaporates and cools the leaves. Conversely, in a water-deficit situation, little water is transpired and the leaf temperature increases.

Canopy temperature is measured using an infrared thermometer, illustrated in Figure 11 below. The thermometer detects long-wave radiation that is emitted by the crop canopy and converts the radiation into an electrical signal that is displayed as a temperature value (Plant Stress, 2008).

Figure 11. Infrared thermometer.
www.plantstress.com/methods/IRT_protocol_files/image002.jpg

Fourth method: the computer model and weather station data method of monitoring soil moisture

The Irrigation Management Climate Information Network (IMCIN) is an irrigation scheduling decision support system that utilizes the nearest meteorological station data to assist in scheduling irrigation operations.

This meteorlogical data can be downloaded to the Alberta Irrigation Management Model (AIMM) and used to determine appropriate times for irrigating.

The model requires input by the producer on seeding date and beginning soil moisture content. It can then track moisture use based on the meteorlogical data, creating a moisture use curve. The moisture use curve can be corrected to measured soil moisture values throughout the growing season if desired.

AIMM predicts the moisture use for an upcoming period based on historic weather data for the selected site. This function allows a producer to forecast an irrigation requirement. Further information regarding the AIMM program can be found at www.agric.gov.ab.ca/app/49/imcin/aimm.jsp.

Crop water requirements

Once the water holding capacity of the soil has been established and a method of measuring determined, the final steps are to determine and monitor the crop's consumptive use. The amount of irrigation a crop requires relates to the type of crop grown, selected variety, development stage, target yield, crop management, and climatic conditions.

Seasonal crop water use or seasonal evapotranspiration is the amount of water used by a plant for growth and cooling processes. Daily evapotranspiration rate increases as the crop matures and reaches a maximum use per day during the critical periods of flowering and seed set or, for perennial crops after cutting or grazing.

Table 9 summarizes the total water requirements and peak moisture use of irrigated crops in Saskatchewan.

Table 10 describes the critical water requirement and termination periods for specific crops grown under irrigation in Saskatchewan. The critical irrigation period coincides with the crop development stage that accumulates daily peak water use, which is shown in Table 9.

Tables 11 to 16 provide the average daily crop water use figures for specific crops based on date of emergence, development stage and temperature.

The rooting zone of a crop determines the amount of water available to the crop. Crops with shallow rooting depths have a smaller zone from which water can be extracted. As such, irrigation timing and scheduling becomes more critical than as compared to deep rooted crops. Allowable depletion, expressed as a percentage is the amount of soil water that can be extracted prior to requiring an irrigation application.

Crops vary in their ability to extract water from the soil thus allowable depletion levels are crop specific.

Table 9 provides detailed allowable depletion information.

Table 9. Total water requirements of crops grown under irrigation in Saskatchewan.

Crop	Seasonal Crop Water Use (mm)	Peak Moisture Use (mm/d)	Active Root Zone (m)	Allowable Depletion (%)
Alfalfa	620	8.0	1.2	60
Grass	500	7.0	0.8	50
Potatoes	520	6.0	0.8	40
Faba beans	610	8.0	0.8	35
Corn				
Silage	470	6.0	1.0	50
Wheat				
Hard	460	7.0	1.0	50
Soft	480	7.0	1.0	50
Canola	430	7.0	1.0	50
Flax	410	7.0	1.0	50
Peas	400	6.0	0.8	40
Barley				
Forage	390	7.0	1.0	50
Malt	430	7.0	1.0	50
Dry beans	380	6.0	0.8	40

Table 10. Critical water requirement periods for crops grown in Saskatchewan

Crop	Critical Water Requirement Period	Irrigation Termination Period
Alfalfa	All the time, especially after cutting	Prior to killing frost
Grass	All the time	Prior to killing frost
Wheat: Hard spring Soft spring	 Tillering and flowering Tillering and flowering	 Soft dough Late soft dough
Barley	Tillering through flowering	Soft dough
Canola	Late vegetation/spiking through flowering and pod development	Initial seed ripening
Flax	Flowering	Prior to seed ripening
Corn: Grain Grazing Silage	 Tasseling and grain filling Tasseling and grain filling Tasseling and grain filling	 Dent stage Dent stage Three weeks prior to harvest
Peas	Beginning of flowering	Pod filling
Potatoes	Tuber initiation and tuber bulking	Beginning of vine ripening
Dry beans	Late bud through pod formation	Mid-August
Faba beans	Beginning of flowering	When half the pods are filled

Table 11. Average daily wheat water use (mm/day) (Lundstrom et al., 1995).

Week after Emergence	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temperature														
10-15°C	1.0	1.0	1.0	1.8	2.0	2.2	2.2	2.2	2.2	2.2	2.0	1.8	1.0	1.0
15-20°C	1.0	1.2	1.8	2.8	3.5	3.8	3.8	3.8	3.8	3.8	3.5	2.8	1.8	1.0
20-25°C	1.0	1.8	2.5	3.8	4.8	5.3	5.3	5.6	5.6	5.6	5.0	4.0	2.5	1.5
25-30°C	1.2	2.0	3.0	4.6	5.8	6.3	6.3	6.6	6.6	6.6	5.8	4.8	3.0	1.8
30-35°C	1.5	2.5	3.3	5.3	6.9	7.4	7.4	7.6	7.6	7.6	6.9	5.6	3.5	2.2

2 tiller, Joint, Boot, Heading, Flower, Early Milk, Early Dough, Hard Dough

Table 12. Average daily barley water use (mm/day) (Lundstrom et al, 1995).

Week after Emergence	1	2	3	4	5	6	7	8	9	10	11	12	13
Temperature													
10-15°C	1.0	1.0	1.0	1.8	2.2	2.2	2.2	2.2	2.2	2.0	1.5	1.0	1.0
15-20°C	1.0	1.2	2.0	3.3	3.8	3.8	3.8	3.8	3.8	3.5	2.5	1.8	1.0
20-25°C	1.2	2.0	3.0	4.6	5.3	5.3	5.3	5.6	5.6	5.0	3.8	2.5	1.0
25-30°C	1.5	2.2	3.5	5.6	6.3	6.3	6.3	6.6	6.6	5.8	4.3	3.0	1.0
30-35°C	2.0	2.8	4.0	6.3	7.4	7.4	7.4	7.6	7.6	6.9	5.0	3.5	1.2

4 Leaf — Heading — Milk

Table 13. Average daily corn water use (mm/day) (Lundstrom et al., 1995).

Week after Emergence	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Temperature																	
10-15°C	1.0	1.0	1.0	1.2	1.5	1.8	2.0	2.2	2.2	2.2	2.0	2.0	2.0	2.0	2.0	1.5	1.2
15-20°C	1.0	1.0	1.5	2.0	2.5	3.0	3.5	3.8	3.8	3.8	3.3	3.3	3.3	3.3	3.3	2.0	1.8
20-25°C	1.0	1.2	2.0	2.8	3.5	4.3	5.0	5.6	5.6	5.6	4.6	4.6	4.6	4.6	4.3	2.8	2.2
25-30°C	1.0	1.5	2.5	3.3	4.3	5.0	6.1	6.6	6.6	6.6	5.6	5.6	5.6	5.6	5.3	3.5	3.0
30-35°C	1.2	1.8	2.8	3.8	4.8	5.8	6.9	7.6	7.6	7.6	6.6	6.6	6.6	6.6	6.3	4.3	3.5

3 Leaf — 12 Leaf — Tassel — Silk — Pollinate — Blister Kernel — Early Dent — Dent — Black Layer

Table 14. Average daily potato water use (mm/day) (Lundstrom et al., 1995).

Week after Emergence	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Temperature															
10-15°C	1.0	1.0	1.0	1.0	1.5	2.0	2.2	2.2	2.2	2.0	2.0	2.0	1.8	1.8	1.5
15-20°C	1.0	1.2	1.8	1.8	2.8	3.3	3.5	3.8	3.8	3.3	3.3	3.3	3.0	2.8	2.2
20-25°C	1.2	2.0	2.5	2.5	3.8	4.8	5.3	5.6	5.6	4.6	4.6	4.6	4.3	4.0	2.8
25-30°C	1.2	2.2	3.0	3.8	4.6	5.6	6.3	6.6	6.6	5.6	5.6	5.6	5.0	4.8	3.5
30-35°C	2.0	2.5	3.5	4.3	5.3	6.6	7.4	7.6	7.6	6.6	6.6	6.6	6.1	5.8	4.3

Budding — Full Cover

Table 15. Average daily pinto bean water use (mm/day) (Lundstrom et al., 1995).

Week after Emergence	1	2	3	4	5	6	7	8	9	10	11	12	13
Temperature													
10-15°C	1.0	1.0	1.2	1.5	1.8	2.0	2.2	2.2	2.2	2.0	2.0	1.8	1.8
15-20°C	1.0	1.2	2.0	2.2	3.0	3.5	3.8	3.8	3.8	3.3	3.3	3.0	2.8
20-25°C	1.2	1.8	2.5	3.3	4.3	5.3	5.6	5.6	5.6	4.6	4.6	4.3	3.8
25-30°C	1.5	2.0	3.3	4.0	5.0	6.1	6.6	6.6	6.6	5.6	5.6	5.0	4.6
30-35°C	1.8	2.5	3.8	4.6	5.8	7.1	7.6	7.6	7.6	6.6	6.6	6.1	5.3

4 Leaf | Flower Auxillary Bud | Podding | Initial Stripe | Leaf Yellow | Maturity

Table 16. Average daily alfalfa water use (mm/day) (Lundstrom et al., 1995)

	First 4 weeks after growth starts in the spring				First 3 weeks after 1st and 2nd cut			First 3 weeks after 3rd cut			Use this section for the weeks not covered in the previous sections for the respective months				
	1	2	3	4	1	2	3	1	2	3	May	June	July	August	Sept
Temperature															
10-15°C	1.0	1.0	1.2	1.5	1.5	1.8	2.2	1.2	1.5	2.0	2.0	2.2	2.2	2.0	1.8
15-20°C	1.0	1.8	2.2	2.8	2.5	3.0	3.5	2.2	2.5	3.0	3.3	3.8	3.8	3.3	2.5
20-25°C	1.2	2.5	3.5	4.0	3.8	4.6	5.3	3.0	3.5	4.3	4.8	5.3	5.6	4.6	3.3
25-30°C	1.5	3.0	4.3	4.8	4.3	5.3	6.3	3.8	4.6	5.3	5.8	6.3	6.6	5.6	4.3
30-35°C	2.0	3.5	4.8	5.8	5.0	6.1	7.4	4.3	5.3	6.3	6.9	7.4	7.6	6.6	5.0

Table 17. Average daily canola water use (mm/day) (Alberta Agriculture, 2005)

Calendar Date		Average Daily Water Use (mm/day)
May	11-20	1.1
	21-31	1.7
June	1-10	3.2
	11-20	4.9
	21-30	6.5
July	1-10	7.4
	11-20	7.7
	21-30	7.1
August	1-10	6.0
	11-20	4.4
	21-31	~
September	1-10	~
	11-20	~

Irrigation System Operation

The amount of water an irrigator can apply during a single operation or the irrigation season is physically limited by the system efficiency and application rate.

Table 18 lists the application efficiencies of different irrigation equipment and Table 19 provides application rates of centre pivots.

Table 18. Approximate application efficiencies of irrigation equipment.

	Irrigation Efficiency
Side roll	0.75
Centre pivot	0.80
Linear move	0.80 +
Centre pivot with drops	0.85
Gravity	0.60

Table 19. Centre pivot application rates based on a 133 acre pivot.

		US gpm							
		600	**700**	**800**	**900**	**1000**	**1100**	**1200**	**1300**
Hours to complete circle	**24**	0.191	0.223	0.255	0.287	0.319	0.351	0.383	0.415
	48	0.383	0.447	0.510	0.574	0.638	0.702	0.765	0.829
	72	0.574	0.670	0.765	0.861	0.957	1.052	1.148	1.244
	96	0.765	0.893	1.021	1.148	1.276	1.403	1.531	1.658
	120	0.957	1.116	1.276	1.435	1.595	1.754	1.914	2.073
	144	1.148	1.340	1.531	1.722	1.914	2.105	2.296	2.488
	168	1.340	1.563	1.786	2.009	2.233	2.456	2.679	2.902

For example, a canola crop can require 356 mm (14 inches) of irrigation during a growing season. To account for the application efficiency of a centre pivot at 0.80, the total amount of water applied equals 445 mm (17.5 inches).

If the system is designed to provide seven U.S. gallons per minute per acre (7.5 mm per acre per day or 0.3 inches per acre per day), the system would have to operate 52.5 days to apply 445 mm (17.5 inches).

This example indicates that if an irrigator is not accounting for the limitations of the irrigation equipment, then the crop may still be lacking sufficient moisture regardless of how effectively or efficiently other aspects of irrigation management are monitored.

Irrigation scheduling assistance

Agrologists with the Irrigation Development Branch of the Saskatchewan Ministry of Agriculture are located in Outlook and Swift Current. They work in co-operation with the Irrigated Crop Diversification Corporation to provide technical, on-farm assistance to irrigators throughout the province. For more information, please contact the Irrigation Development Branch in Outlook at 867-5500 or Swift Current at 778-5041.

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